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Definition of S nar System

DEVELOPMENT PLAN

Prepared for the
Transportation Development Centre
Transport Canada

November 1983

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DEFINITION OF SONAR SYSTEM

DEVELOPME PLAN

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by

SCANNAR INDUSTRIES INC.
1800 Vincent Massey Drive
Cornwall, Ontario
Canada

November 1983

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17. Abstract

The results of a study to employ sonar technology to detect navigational hazards in the Arctic are reported. The need for this study resulted from increased navigation in Arctic waters (oil and gas exploration) and concern for safety and risk to the environment. Problems such as sonar beam refraction and reverberation levels brought about by the severe environmental conditions are predictable, however, target (growler/pingo) characteristics have not been previously examined. A data gathering mission is proposed to provide information on target characteristics. Analysis of the data will determine the capability and level of signal processing required to detect hazards at high reverberation levels. This will facilitate the prototyping of the proposed system that consists of a vessel (bow)-mounted sonar system with an ice-hardened transducer and a helicopter-deployed, towed-body, swath sonar system. The vessel-mounted system is a 15 kHz, high resolution sonar that provides detection coverage in a 64° forward sector for a range of 3.7 km (2 nautical miles) under ideal conditions. As environmental conditions deteriorate, the helicopter-deployed sonar system is introduced to provide detection coverage of the range lost. Shortcomings of using sonar as a hazard detection system are discussed. A schedule for the development and construction of the proposed system is provided with budgetary pricing.

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17. Résumé

Ce rapport rend compte de l'étude d'un sonar pour la détection des glaces flottantes, dont la nécessité augmente à mesure que s'intensifie la navigation maritime dans l'Arctique (mise en valeur des gisements de pétrole et de gaz dans cette région) et que se précisent les normes de sécurité et de protection de l'environnement; il fait aussi le lien entre les conditions climatiques qui règnent dans cette région et les conditions de réfraction et de réverbération qu'elles imposent au faisceau sonar. Les caractéristiques physiques des cibles visées demeurant encore inconnues, il est proposé de lancer un projet pour combler cette lacune et pour rassembler des données dont l'analyse permettra de déterminer les caractéristiques techniques à donner aux équipements pour le traitement des signaux reçus, noyés dans des bruits de réverbération élevés. Il sera alors possible d'étudier un prototype de système de détection double, composé d'un sonar de proue à transducteur sous dôme résistant aux glaces et d'un sonar monté sur support à deux coques et remorqué par un hélicoptère. Le sonar de proue haute résolution fonctionnant dans la bande des 15 kHz est capable de balayer une aire de 64° à une distance de 3,7 km (2 milles marins) lorsque les conditions climatiques sont bonnes. Autrement, on fera appel au sonar remorqué compensant ainsi la distance de détection perdue. Le rapport traite des points faibles du sonar dans l'application envisagée et propose un programme d'étude et de construction accompagné d'un devis estimatif.

18. Mots-clés	19. Diffusion
Sonar haute résolution. Détection/ évitement des glaces. Transducteur sous dôme résistant aux glaces. Caractéristiques du sonar.	Le CDT dispose d'un nombre limité d'exemplaires

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SUMMARY

This report presents a study of the employment of a sonar system for detecting floating and submerged ice hazards in Arctic waters in a 60° forward sector with a range of 2 nautical miles (3.7 km).

The main tasks of this study were:

i. Define the problem and provide solutions.

ii. Propose a suitable system and describe its application.

iii. Develop/prepare the design concept and expected performance.

iv. Propose a method for testing the system.

v. Define a schedule of activities for the development and testing of the system.

vi. Prepare budgetary estimates for this schedule of activities.

Thorough investigation of the severe conditions for sonar operation in Arctic waters still leaves some questions unanswered. These answers need to be provided in a proposed data-gathering phase to provide information for the development of an ice hazard detection system.

In order to satisfy the requirements, a dual sonar system is proposed to provide ice hazard detection even under worst conditions. A hull-mounted high resolution sonar and a dunking (towed body) sonar mounted in a helicopter comprise this dual system.

The estimated period for full development of this system is 3 years plus.

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1. INTRODUCTION

The discovery of oil and natural gas in the Arctic along with the development of arctic class vessels have increased navigation through the ice infested waters of the north. In order to ensure safe travel and eliminate the risk to the environment, it has become necessary to detect obstructions such as icebergs and growlers well within the manoeuvering time frame of the vessel. Radar and thermal infrared (IR) scanning equipment have proven to be capable of detecting certain hazards; however, both have serious deficiencies. Radar does not perform well at short ranges or high sea states and IR is severely reduced with poor weather conditions. Obstacles that are completely submerged cannot be detected by either device. For these reasons, sonar appears to be the most viable method of ice hazard detection.

The complex and hazardous nature of this application of a sonar system requires several innovative new designs for the transducer, the signal processing and installation.

This report outlines design concepts, a preliminary system specification, details of design implementation phase and budgetary estimates.

2. PROBLEM DEFINITION

2.1 Definition of Basic Problem

The fundamental problem is the detection of submerged and floating ice hazards such as "pingos" and "growlers" in various sea states, and at sufficient range to enable a vessel to manoeuvre safely.

Sonar seems to be the most viable answer to this problem, however, the solution may be only a partial one. This application presents many severe conditions affecting sonar operation and performance. Problems such as small target size relative to required detection range, complex interaction of the acoustic wave with the medium (water), varying target characteristics, all present a great challenge to the conventional sonar.

2.2 Effects on Acoustic Waves by Medium

Varying medium conditions including sea state, temperature and pressure cause acoustic waves to weaken, reflect and refract.

2.2.1 Weakening of Waves (Transmission Loss)

Transmission loss is the tendency of an acoustic wave to weaken as it travels from the source of transmission out through the medium. The magnitude of this loss is determined by wave frequency, spreading effect, temperature and salinity.

As the frequency increases, the useful range decreases. Consequently, for the longer ranges specified here (3.7 km or 2 nautical miles) a low frequency sonar is required. The optimum frequency is discussed in Section 2.2.3.

Water temperature can affect an acoustic wave in several ways. If the temperature remains constant over depth (isothermal water), lower temperatures reduce effective sonar range. Salinity concentration also affects sonar range. As salinity concentration increases, range decreases.

2.2.2 Reflection of Wave (Reverberation)

Reverberation is the unwanted multiple reflections of an acoustic wave caused by the surface, the bottom and other water interference. These effects can cause serious complications to the application. Reverberation will tend to obscure targets near the surface at longer ranges.

Since the target and swell may produce the same sonar signal, the sonar system will not be distinguishable., Also, higher sea states amplify these effects. Reverberation effects can be offset by using short transmission pulse lengths and narrow beams.

The magnitude of these reflections must be measured to determine critical points at which reverberation levels make target detection impossible. The results will also assist in determining exact system specifications.

2.2.3 Sonar Performance: Range versus Beamwidth
(See Fig. 1 - Sonar Performance Graph)

Low frequencies, narrow beams, and short pulses are used to counteract transmission loss and reverberation.

Fig. 1 - "Sonar Performance" shows the relationship between horizontal beamwidths versus noise-limited range at selected frequencies. Surface reverberation at selected sea states is also shown as a limiting factor at different ranges.

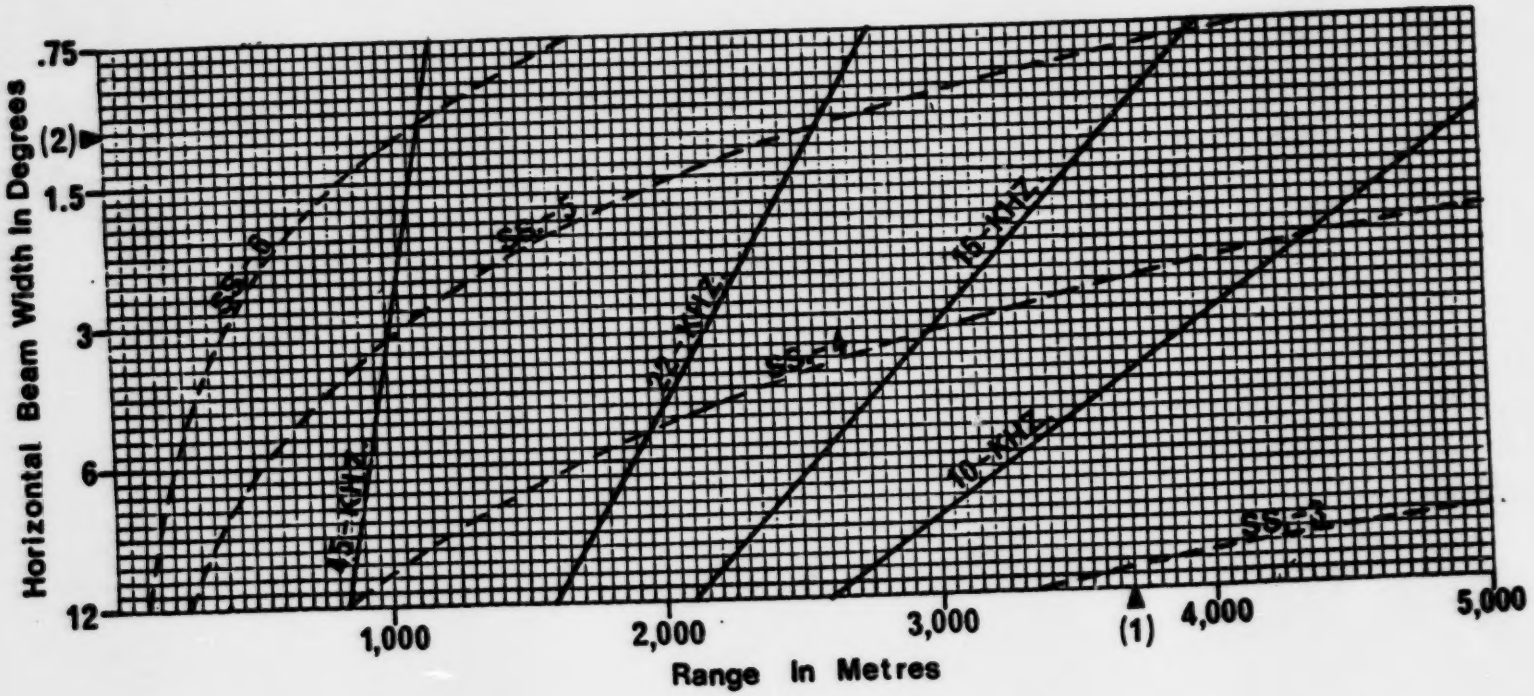
The following assumptions were made in constructing the graph: represent typical conditions.

(a) pulse length of 1 metre permits higher range resolution which contributes to the reduction of reverberation;
(b) spherical target of 10 metres diameter reflecting 10% of the acoustic energy uniformly in all directions (typical growler);
(c) "Recognition Differential" is a ratio of amplitudes, i.e., target strength versus unwanted background noise. At 6 db the target strength is twice that of the background. Using the assumed pulse length of 1 metre, the recognition differential required is 16 db. It is assumed that there will be a 10 db gain from using correlation techniques in processing and;
(d) "Ray Path" is the direction of the acoustic horizontal wave which is determined by water temperature; assumed to be 0°C, to maximize the temperature effects.

For example, referring to arrow indicator (1) on the graph, at a range requirement of approximately 4000 metres, it can be determined that only 2 of the illustrated frequencies are feasible - 10 kHz or 15 kHz. Sea state curves show that narrow beamwidths are required for both frequencies. To operate in SS.5 would require a 22 kHz with a beamwidth of 1.25 degrees (2) (for this example).

NOISE LIMITED RANGE VS. BEAMWIDTH AT VARIOUS FREQ. ——————

SURFACE REVERBERATION LIMITED RANGE VS. BEAMWIDTH AT VARIOUS SEA STATES - - - - - -



Assumptions:

Pulse Length 1 Metre
Target 10 Metre Sphere
10 % Reflectivity
Recognition Differential 6 db. (10 db processing gain)
Horizontal Ray Path in 0°C Water

FIGURE 1 SONAR PERFORMANCE GRAPH

2.2.4 Refraction of Wave (See Fig. 2 - Ray Path Coverage of 3° Vertical Beam)

Soundwaves bend or refract toward areas in a medium where they propagate at lower velocity, as do radio waves, light waves, wind and water currents, etc.

In the ocean, the two major influences on sound velocity are temperature and depth. Each directly affects sound velocity and usually counteract each other to produce sound channels. Where soundwaves are refracted downward, then upward, etc., the paths that the waves travel are known as "ray paths". Ray paths are predictable from bathythermograph information that is derived from temperature profile measurements taken from records or from actual on the spot measuring.

In the Arctic, waves propagated near the surface, in summer, will suffer downward refraction from high surface temperatures, and in winter will be refracted upwards by pressure.

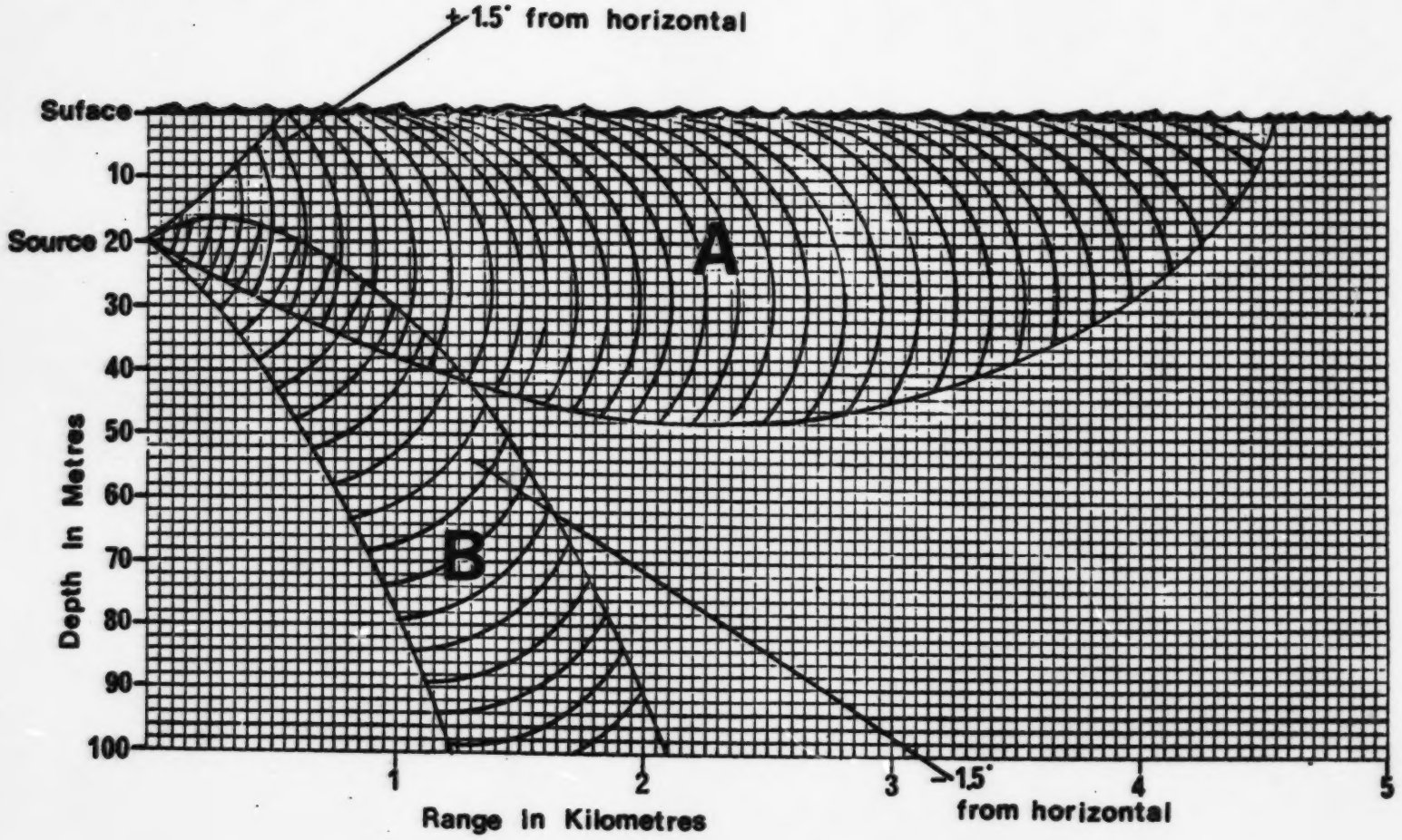
Summer propagation will be affected by warming and cooling of surface water due to mixing wind and currents. Since these conditions are highly variable, only on the spot measurement of temperature profile will provide accurate information.

Similarly, near-surface mixing of air and water in various sea states will cause upward refraction. Since these conditions are also highly variable, on the spot sound velocity profile measurements will provide accurate information.

Uniform salinity usually presents no problem, however, changes in salinity caused by melting icebergs, etc., may cause refraction and obscure other nearby hazards. The extent of these variations need to be studied to determine to what extent this affects the situation.

2.2.5 Ray Path Variation (See Fig. 2 - "Ray Path Coverage of 3° Vertical Beam")

Fig. 2 - "Ray Path Coverage of 3° Vertical Beam", which follows, illustrates various ranging problems that could exist at different times of the year due to a change in sound velocity with depth or temperature. Change in sound velocity will occur even in the absence of a thermocline in isothermal water as indicated by curve A. This is due to the velocity gradient which is proportional to pressure and therefore depth. The result is an upward bending of the ray path which in turn results in signal reflection at the surface. This reduces the range due to attenuation at the skip point. These conditions may occur throughout



A- Isothermal (Sound Velocity Gradient = .017)
B- Temp. Variance (Sound Velocity Gradient = .1)

FIGURE 2 RAY PATH COVERAGE FOR 3° VERTICAL BEAM

the winter, or during high sea states in summer where air and surface water mix sufficiently to cause upward bending of the ray.

Curve B is more typical of the summer months, where the surface has been warmed considerably causing an increase in sound velocity nearest to the surface. This will cause the beam to refract downward, thus limiting the range capabilities of the sonar.

2.2.6 Solving Problems of Refraction

In order to guarantee sonar detection in an unpredictable ray path situation such as that anticipated in the Arctic summer, a very flexible sonar and sonar platform is required.

Extreme velocity gradients suggest a need for a platform whose depths can be varied, combined with a tiltable sonar. This would permit the range to be optimized so as to counteract these refractive effects. These are the only possible solutions and suggest the need for a very flexible, total system.

2.3 Effects on Acoustic Waves by Target Characteristics

2.3.1 Effect of Target Shape and Composition

The acoustic strength of a target depends on the target's absorption and reflection of sound waves. These in turn will vary with the target's shape and composition/density. Targets may contain rocks, be covered with slush, have varying ice densities, etc., which will require interpretation by the sonar.

2.3.2 Effects of Target Movement

Sea swell will cause growlers to bob, appearing and disappearing on the surface. They may trap air during this movement which would affect the returning signal making them appear larger than they would in calm sea conditions.

2.4 Summary and Conclusion

The application of sonar in the Arctic environment for the detection of ice hazards to navigation is feasible. Its performance however will be constantly affected by the environmental conditions resulting in reduction of guaranteed operating range (range of hazard detection) as conditions worsen. This operating range can be accurately determined by on the spot measurement of temperature profiles (or sound velocity profiles) on a daily or even hourly basis.

Other performance affecting factors still need to be studied. Some of these are:

i. Salinity changes around melting icebergs that may produce beam refraction that obscure other nearby hazards
ii. Bobbing growlers and target characteristics and how these affect the sonar signal
iii. Reverberation levels and the effects of swell on the short pulse length
iv. Mixing time for thermocline changes
v. Noise effects from breaking ice
vi. Noise effects transmitted from hull to transducer.

To compensate for the reduced range, two alternatives are feasible. One is to reduce the speed of the vessel to remain in a reduced manoeuvreability area, should an ice hazard be detected at a shorter range. The other is to provide a second sonar system ahead of the main vessel to cover the range lost due to the environmental conditions.

It seems that the latter is more acceptable since the vessel may proceed at the original speed. Further, short operating range conditions often prevail when calm above water conditions are present, therefore allowing a helicopter to provide forward spotting of hazards by an onboard dunking sonar system. Still, there may be environmental conditions where operation at a reduced range was the only possibility.

3. PROPOSED SYSTEM & OPERATION

3.1 Basic Configuration

The proposed ice hazard detection/collision avoidance sonar system consists of two separate sonars, one in a hull mounted configuration and the other is a helicopter installation. These two sonars will provide a detection coverage in a 60° forward sector to a range of 2 nautical miles (3.7 km) even during most of the extreme environmental conditions. The operational (detection) range is always made available by this same system by a computation that converts measured temperature profile data to operating range.

Both of these systems should be high resolution sonars utilizing digital techniques and signal processing to allow for a high level of modularity, flexibility and implementation of algorithms to achieve target recognition even at a very low recognition differential encountered in this application.

Figure 3, "Proposed System", depicts the application and system operation.

3.1.1 Hull Mounted System

The hull mounted sonar system should comprise a 15 kHz sonar with 0.5° horizontal resolution (i.e. 0.5° by 4° beams) to provide ice hazard detection capability optimal range to 1146 metres under ideal conditions. At this range a 10m growler would be the same width as the 0.5° beam. However, with the application of processing techniques such as moving correlator, supported by ship's log and gyro compass, the system is expected to perform to the required range of 3.7 km under ideal conditions. This high level of processing is achievable by filtering out noise and reverberation to enhance target recognition that would otherwise be attainable by a beam of 0.15° width.

This system shall be capable of operating up to sea state 5 (See Fig. 1) with vertical stabilization employed to counteract ship roll and pitch. Target range and bearing would be presented visually on a monitor while making the same data available to an integrated display system.

The transducer array may replace plating in the vessel's bow section. The exact location can be determined by the bow's design, with special attention given to strengthening members. The most favorable location is as deep underwater

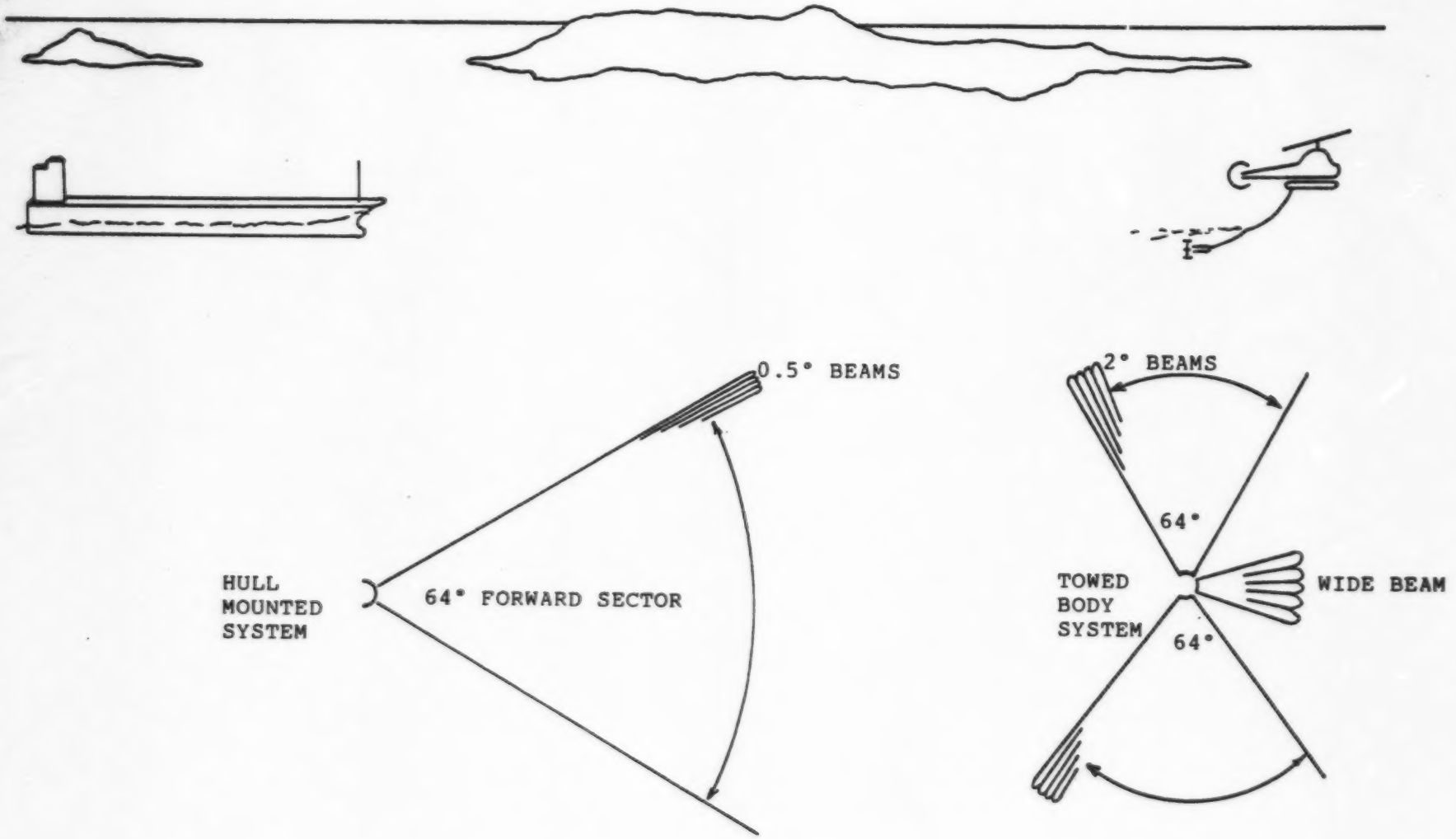


FIGURE 3 PROPOSED SYSTEM

as possible to minimize interference from air bubbles and ice and maximize the transmission range of the sonar whereby electronic tilt can be employed to counteract beam refraction. See Figure 4 Transducer Location and Figure 5 Transducer Location Closeup.

The transducer array for this 15kHz system would consist of 2048 single element transducers that would occupy an area roughly 1 metre by 12 metres. Additionally, the transducer should be capable of withstanding impact from broken ice and still remain operational (i.e. it is to be at least as hard as the hull).

3.1.2 Towed Dunking Sonar

The towed dunking sonar should be a stand alone system easily deployed in a helicopter that will allow this system to operate ahead of the vessel's hull mounted system when environmental conditions deteriorate the performance of the hull mounted system. In this configuration, the vessel may proceed at the same speed since the required 3.7 km detection range is upheld.

This sonar system should be a 45 kHz system with a 2° resolution to provide ice hazard detection swath of optimal range to 573 m. (This is the range at which a 10m target is equal to the beam width.) With the application of the same processing techniques as the hull mounted system, required target detection capability will be extended to cover a swath of 3.2 km.

The requirement to provide a high frequency, somewhat lower resolution sonar system is necessitated by the size and weight constraints for a helicopter installation. Weight and size are proportioned to system frequency and resolution. The proposed 45 kHz system offers the best trade off of weight resolution and range and would be suitable for this application. (See Figure 1 Sonar Perform-Graph)

The towed body should be designed to provide stabilization while being towed. Besides the x by y transducer array at each side, the towed body should accomodate a gyro compass, pressure sensor, temperature sensor, and sound velocity sensor. The cable should be a 50 metre armoured cable with 250 conductors that would provide the electronic connection as well as the provision for towing. (See Figure 6)

A visual display indicating target range and bearing should be provided on the helicopter to allow the operator to identify possible hazards and convey the locations of these hazards back to the ship via conventional communication. This system should also have an automatic data transfer link from the helicopter to the main vessel's sonar system to display the helicopter installed sonar system data.

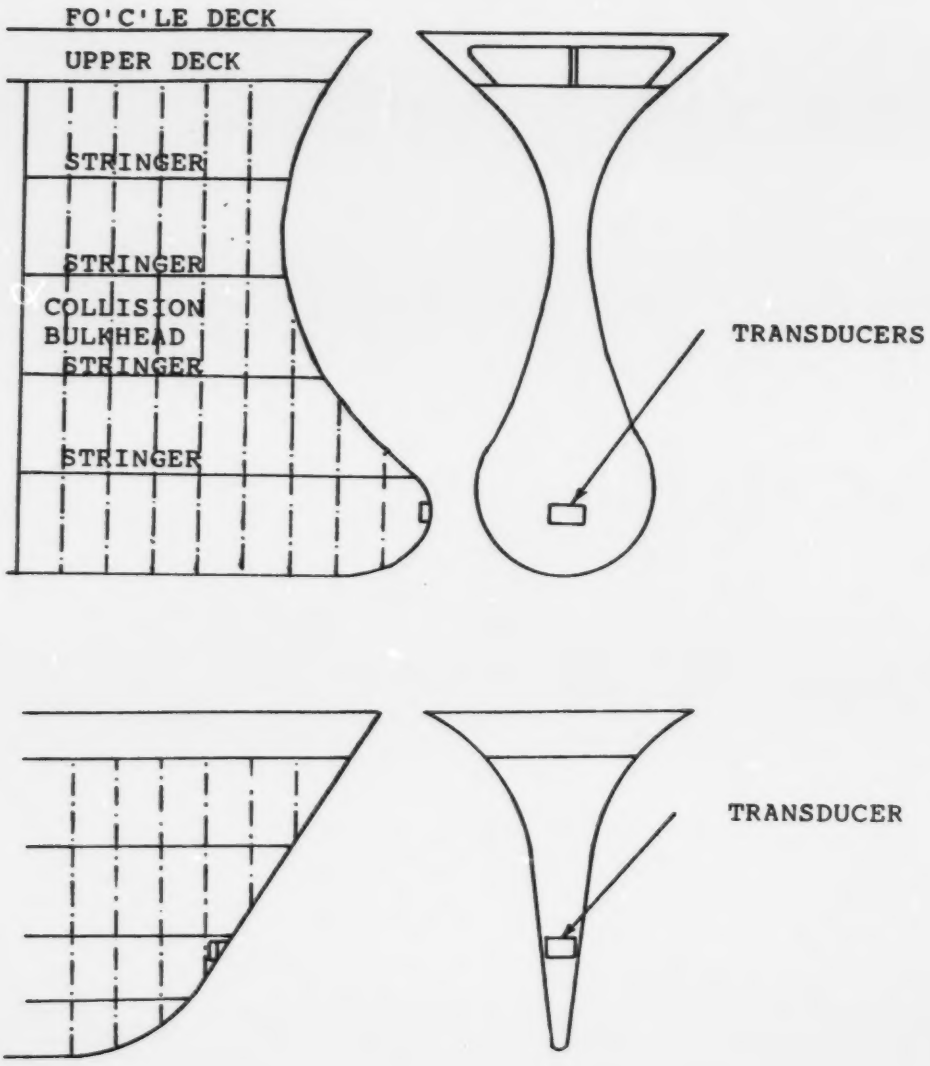


FIGURE 4 TRANSDUCER LOCATION

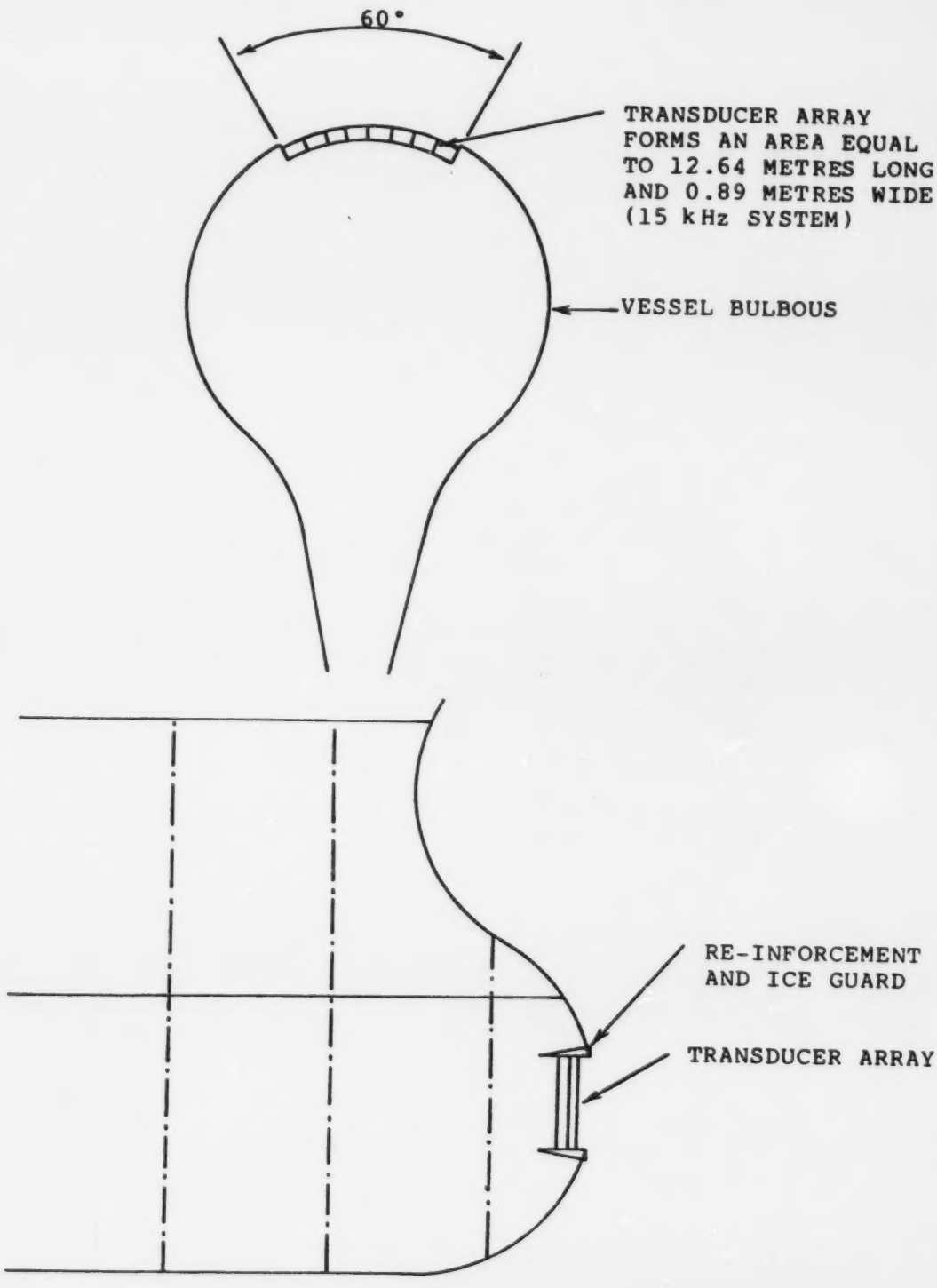
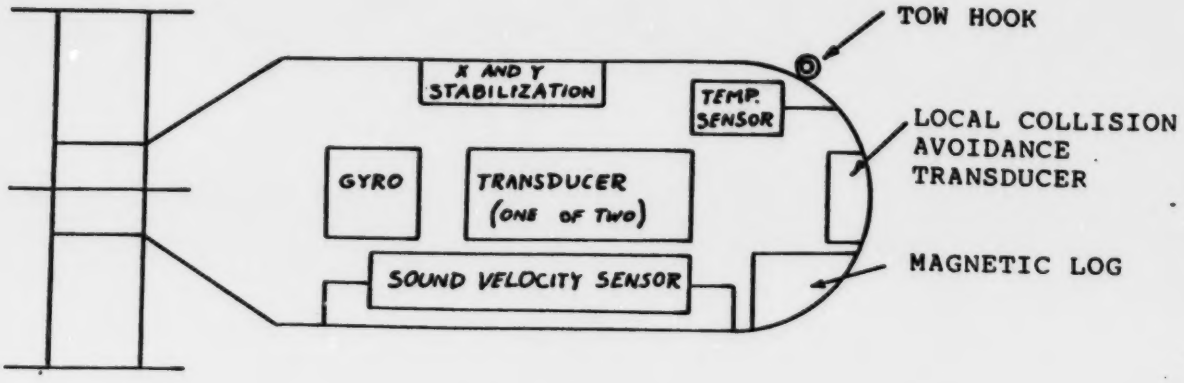


FIGURE 5 TRANSDUCER LOCATION CLOSEUP

SIDE VIEW



TOP VIEW

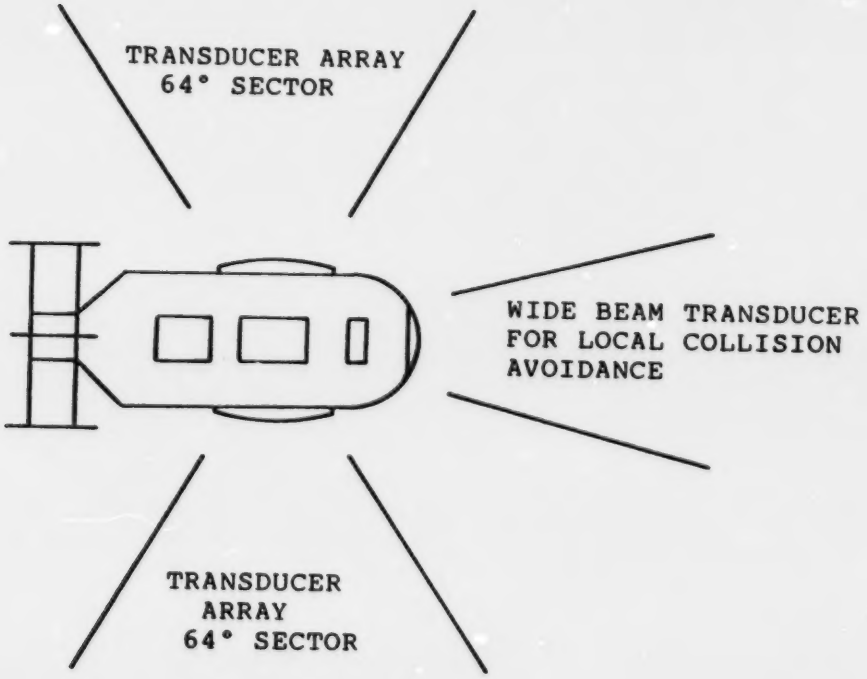


FIGURE 6 TOWED BODY

3.2 System Application & Flexibility

The proposed sonar system will have applications in navigation to detect ice hazards that are floating (growlers, icebergs) as well as those that are submerged (growlers, pingos) in Arctic waters up to sea state six.

Various classes and sizes of vessel navigating in the Arctic waters will have different performance requirements in detecting these hazards. The flexibility of the proposed system is able to provide high performance that is demanded by large vessels as well as scaled down versions for smaller vessels. It is configurable to installation in vessels other than helicopters, such as remote controlled vehicles (RCV's) and submarines.

4. PRELIMINARY SYSTEM SPECIFICATION

The proposed dual sonar system is expected to satisfy the performance requirements in providing detection of a 10m target in a 60° forward sector to a range of 2 nautical miles (3.7 km).

Precise data is to be gathered to provide information on target size and target signal strength that will add to the design factors of this sonar system.

Table 1 is a preliminary specification for both the vessel installation and helicopter installation.

Hull Mounted Sonar Parameters	Specifications
Range on 0db @ SS5	4000 metres
Frequency	15 kHz
Band Width	2 kHz
Sector coverage	64°
Horizontal beam width	0.5°
Vertical beam width effective	4°
Beam width resolution	0.15 ° (equivalent)
Stabilization	Electronic
Transducer	Bow hull plate
Quantity	8 of 256 elements each
Size	0.89m X 12.64m (total size)
Transmit pulse length	Equivalent to 1msec. (min) to 15 msec. (max)
Display resolution	512 X 512 elements

Towed Dunking Sonar Parameters	Specification
Range	1600 m (3200m swath)
Frequency	45 kHz
Band width	2 kHz
Sector coverage	Two 64° sector on each side of body
Horizontal beam width	2°
Vertical Beam width effective	4°
Beam width resolution	0.35° (equivalent)
Stabilization	Electronic
Transducer	Two transducer arrays on each side of towed body
Quantity	4 of 256 elements each
Size	0.3m X 1.2m each

Transmit pulse length	
Gyro compass System	
Depth sensor	
Temperative sensor	
Sound velocity sensor	
Display resolution	256 X 256 elements

Table 1. Preliminary System Specification

5. DESIGN CONCEPT

5.1 Transducer Design & Mounting

In order to achieve the specifications listed in Section 4, the following concepts have to be implemented in the transducer design.

5.1.2 Wide Aperture Array

Narrow beamwidths, both horizontal and vertical will be achieved using wide aperture, multi-element transducer array configurations. Eight transducer arrays, to be mounted on the bow of the vessel, will combine to form the size aperture required. Four transducer arrays, two on each side, to be mounted in the towed body.

5.1.3 Array Mounting Strength

The transducer will employ a thinned array, which refers to the omission of every second element. This design allows a strengthening member to exist between elements. Thus, exceptional physical stability without adversely affecting performance.

5.2 High Pressure Element Design

The transducer arrays have to be designed to operate in a high pressure environment. Additionally, these arrays must be capable of withstanding the impact of broken ice without damage jeopardizing system operation or vessel structure. Therefore, the design has to be such that no weak point is introduced into the sonar system or the vessel structure.

Fig. 7 illustrates design concepts for high pressure transducer elements.

5.3 System Design

Figure 8 illustrates the system design described in this section.

5.3.1 Transceiver Sections

Each of the eight transducer arrays will be interfaced to individual transceiver sections. These 8 transceivers perform the functions of D/A's, by converting digital transmit signals to analog. The transmit signals will be of short pulse length characteristic.

The transceivers also perform the function of A/D's, converting the broadband received analog information to digital data. The received analog information must be sampled at band Nyquist rate in order to assure proper digital reproduction.

The use of narrow vertical beams require that the transceivers perform electronic beam stabilization.

The use of a precise vertical gyro in conjunction with beam tilting compensation techniques will achieve the stabilization required.

5.3.2 Signal Processing Section

Signal processing should consist of beamforming techniques to counter the effects of reverberation and also of a moving memory correlated to filter out the effect of noise. This correlator would employ the vessel's speed log and gyro compass information.

The qualified data, ie., beamformed, correlated data, is to be made available, for analysis by a navigational master computer, via a DMA module.

5.3.3 Control Indicator Section

The Control Indicator is the man/machine interface. It will consist of a high resolution display for visual presentation of the beamformed, correlated data. Detected target range, bearing and depth will be made available to the operator on the display.

An audible alarm upon detection of targets will also be part of the Control Indicator.

An operator control panel is to provide basic sonar ranging and directivity control.

5.3.4 Design Concept Consideration

The sonar systems should be "stand alone" units requiring no additional equipment for display or control. They should, however, have the flexibility to be reconfigured to an integrated display system as these systems become available and are put to use.

This, together with an automated fault locating capability will ease field servicing and give a reliance or dependability level for the system.

Digital designs should include self calibration techniques to compensate for linear component characteristic changes over time.

Operator adjustments and fine tuning of sonar performance could be eliminated. These functions could be automatically implemented and transparent to the user.

The system design should allow for multiples and/or combinations of basic system components in order to configure versions of higher performance systems demanded by larger class vessels. Concurrently omission of basic system components would yield scaled down performance adequate for smaller class vessels.

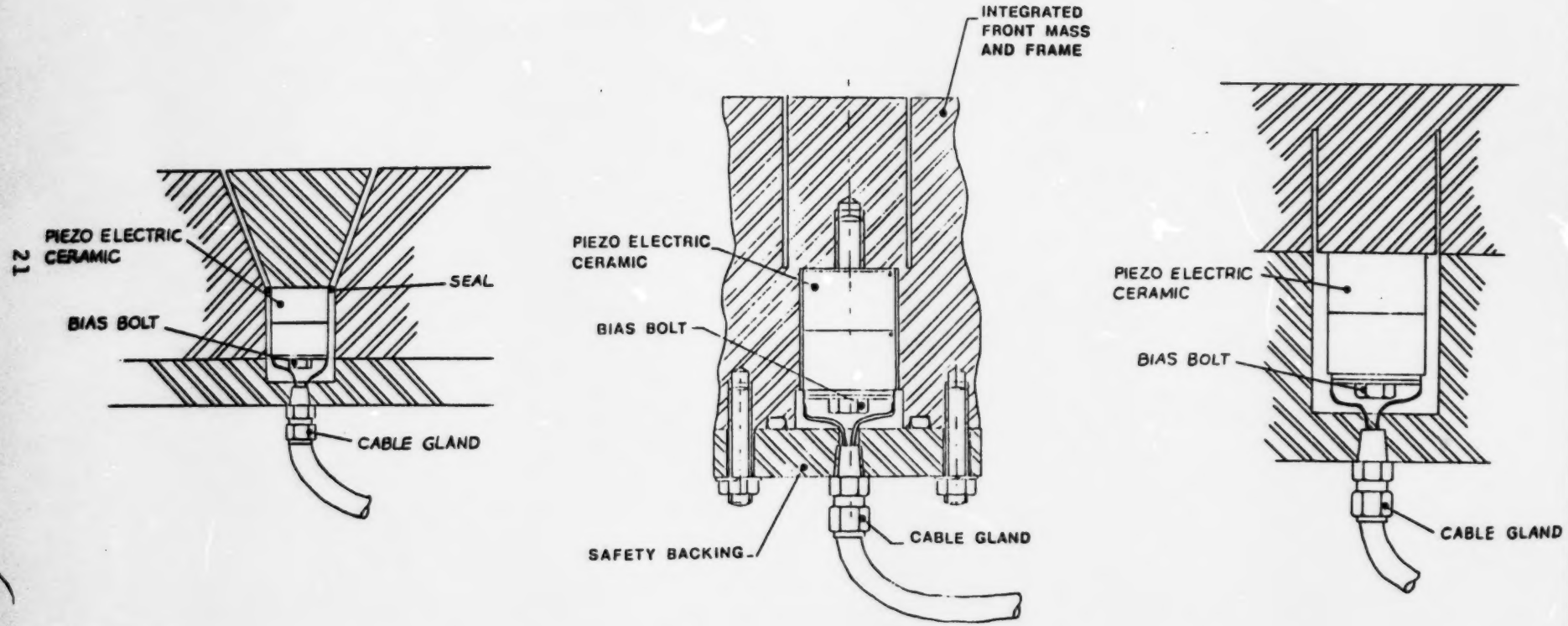


FIGURE 7 HIGH PRESSURE ELEMENTS

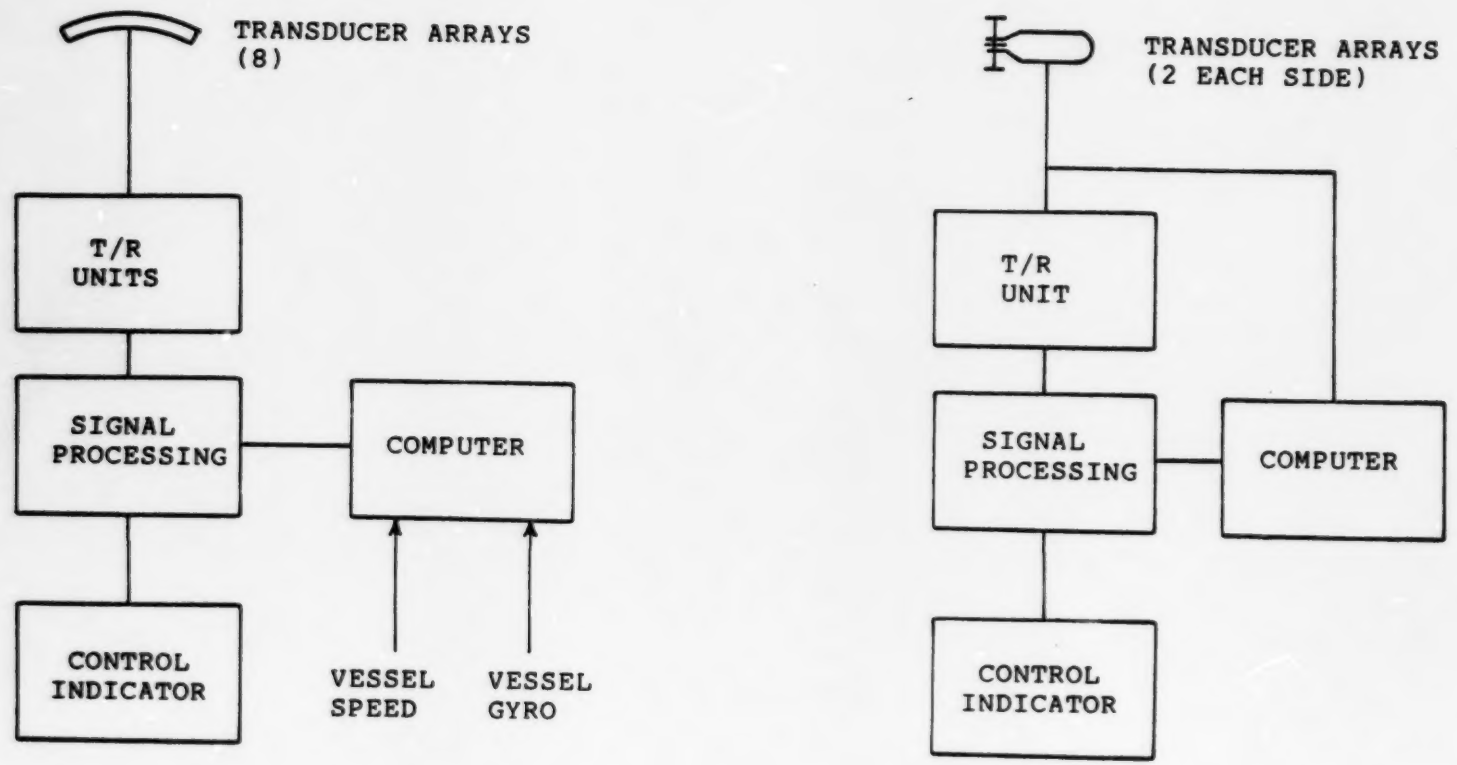


FIGURE 8 BLOCK DIAGRAM OF OBSTACLE DETECTION SONAR SYSTEM

6. PROPOSED METHODOLOGY FOR SYSTEM TESTING AND ALTERNATIVES

A data gathering phase is required to provide information on target characteristics and movement, and the effect of these on the sonar signal, also the effects of breaking ice and vessel hull noise on the hull mounted transducer. This data is essential since it will establish the limitations of the system in target recognition and operational environment while at the same time providing recordings of real conditions that can be used as simulated data for prototype development. Without data accurately characterizing targets, there is more risk associated with prototype development. It is essential that prototype success can be maximized.

The short operational season of the Arctic waters and the difficulty of finding ideal conditions for testing, necessitates an efficient means of carrying out the testing.

Primarily, the system has to be highly portable (i.e. relatively small and light weight) to allow for transportation to areas with ideal conditions for testing (iceberg and growler infested waters). This would also require the ability for quick and easy installation and disassembly.

The proposed system should be a modular sonar system, a sectional version of the proposed unit, that could be assembled and taken to the Arctic for testing. The requirements of portability of this unit necessitates a system that operates at a high frequency and wider beam width at the expense of a reduction of range. However, the information collected will pertain to sonar performance at both range levels where interpolation of figures to the lower frequency is easily achieved. Band Nyquist sampling, variable transmit pulse length and broadband receiving should be incorporated in the system. Figure 9 depicts the proposed system. This system is similar to Figure 8 (block diagram for proposed obstacle detection sonar) where the electronic configuration is the same but this omni sonar configuration has an operational frequency of 45 kHz to reduce the size and weight of the transducer. This is further amplified by the more coarse beam width of 6° vertical and 6° horizontal. This limits the optimal detectable range of a 10m growler to 96m, since at this range the growler will fill the width of one beam. Note that the capability of measuring the characteristics of targets and the medium is not degraded and the only limitation that results is the examination of targets at a shorter

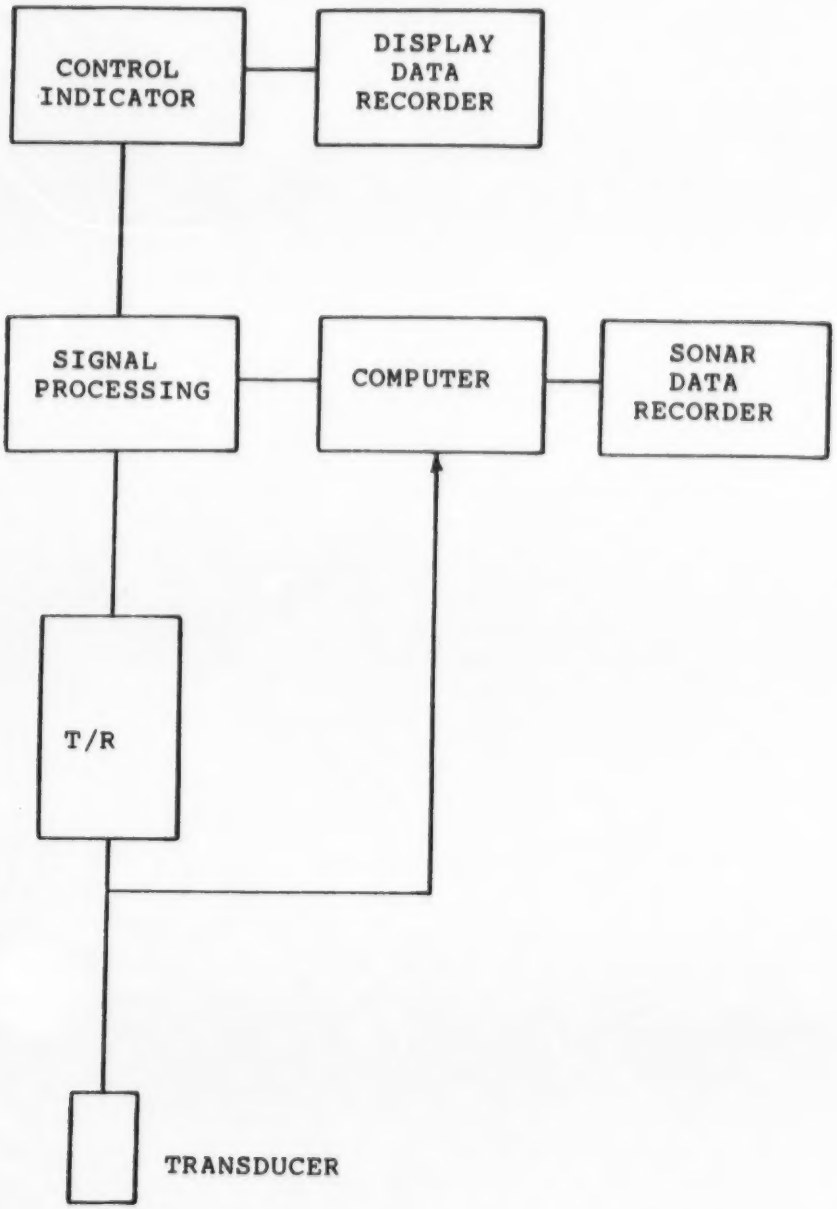


FIGURE 9 BLOCK DIAGRAM OF SECTIONAL VERSION FOR SYSTEM AND DATA GATHERING

range. Note also that the shorter range minimizes the effects of the medium (ray bending) and therefore quarantees accurate data recording.

This phase of testing should utilize data recording consisting of both raw target data and corresponding display data. This together with weather, sea state, and thermocline information would provide the necessary inputs for the full scale model testing to simulate targets and medium characteristics at previously recorded conditions. After all, the testing of the full scale prototype will impose limitations to the testing or at least increase the testing timeframe, therefore any means of simulating operating conditions in the development stage would be a great asset.

This testing methodology is dependant on many factors such as weather conditions, availability of targets for examination, availability of various platforms for test system installation, etc. If enough flexibility is provided for this data gathering phase, these factors may be overcome to provide as much useful data as possible. However, if this phase should, for some reason, be totally fruitless, a more lengthy system testing of a full scale prototype may be implemented. This could be attained if the full prototype were to be installed in a vessel that operates in the Arctic or other Artic-like waters for a longer period of time. There would be a much higher risk associated with building a prototype without having target data known, as outlined previously. It would not be to anyone's advantage to invest heavily in a prototype development program not knowing as much of the physical characteristics as possible.

6.1 Test Platform Requirements

6.1.1 Stability

As previously established, the transducer array must be stabilized in order to control the directivity of the acoustic signals. Since many of the targets are located close to the surface, it will be important to concentrate the beams in this area. As weather conditions worsen, this becomes increasingly difficult due to the agitation of the surface layer. This can be overcome during the data gathering phase by either mechanically stabilizing the transducer array or the platform on which it is mounted.

6.1.2 Manoeuverability

The manoeuverability of the platform is also an important consideration. Ideally measurements should be taken as close to the targets as possible and from different angles in order to obtain the full spectrum of their reflectivity. This must be performed without risk to the equipment or to the platform.

A great deal of time would be saved if the platform was made transportable to the point where it could be easily moved to various regions where hazards are guaranteed to be located.

6.1.3 Versatility

The platform must be capable of operating in various sea states while maintaining the stability requirements of the transducer. This will allow data to be collected over the range of weather conditions in order to establish their exact effects on sonar performance.

The platform should also permit the transducer to be lowered to different depths for study of the thermocline. This will permit adjustment of the transmitting tilt angle to establish the degree to which range can be extended when a temperature gradient exists. Measurements to determine the temperature gradient could be taken at the transducer as it is lowered, otherwise a bathythermograph will be required.

6.1.4 Additional Considerations

The platform used to mount the unit during data gathering must permit visual observation of the targets. The physical characteristics of each hazard will be recorded in addition to their acoustical properties. This information will include shape, size and material composition. Another important limitation on the platform is the amount of noise signal it introduces to the sonar equipment. Measures must be taken to minimize the acoustic interference caused as the unit is being propelled.

6.2 Alternatives

6.2.1 Ship Mounted

This method suggests the installation of the data gathering unit on a ship capable of navigating in the same areas where ice hazards exist. This will require the installation of a well tube in the hull of the vessel to accommodate a 40 cm hole for the transducer and stabilization unit.

6.2.2 Dunking Platform

This method involves the construction of a platform to support and stabilize the transducer. The unit would be suspended over the side of a ship or lowered from a helicopter.

6.2.3 Submersible

This method employs a mini-submarine as a vehicle in which the entire data gathering sonar unit would be installed. The sub is launched from a suitable base platform located near an area where ice hazards are present. The launching platform could be a ship, an oil rig or a dock site.

6.3 Advantages and Disadvantages of Alternatives

Each of the methods for mounting the data gathering sonar has been thoroughly investigated in order to determine which is the best alternative. The method selected must provide the means of collecting all the information required and guarantee success of the mission. In order to present the reasoning applied in establishing the final decision, the advantages and disadvantages of each scheme are presented.

Although the vessel used in the ship mounting method will be well adapted to the Arctic navigation, the low manoeuverability of the ship poses a substantial problem for data gathering. The ability to close in on targets from different angles will be restricted by the size of the vessel and its turning radius. The requirement of a hole for transducer mounting reduces hull integrity and increases the probability of damage to the equipment and to the ship. This type of installation is also very susceptible to the screw noise which could greatly reduce the accuracy of the readings taken. The transducer being fixed to one depth will not permit adequate study of the thermocline effect, a prime objective of the data gathering phase. Visual classification is also very restricted in this approach.

The dunking platform offers increased flexibility to the unit allowing the transducer to be lowered in close proximity to the targets, while decreasing the risk to the main vessel, however, operation during poor weather conditions is practically impossible. If the platform were suspended over the side of the vessel, stabilization of the unit would be quite difficult since it could also be under effect of the main vessel. The unit will also have a tendency to rotate, further complicating the control over the directivity of the acoustic signals. The cables used to connect the transducer to the sonar equipment, mounted in

the main vessel, will be very susceptible to damage. This could cause complete failure of the mission. This mounting method is also incapable of lowering the transducer to various depths for study of the thermocline. Visual classification of the targets is restricted as described in the ship mounted method.

The helicopter installation provides superior manoeuverability, excellent territorial coverage and visual classification, along with the dunking transducer capability and short range target examination. The disadvantages of such a system are restrictions caused by weather and restrictions of the equipment weight.

All of the disadvantages found in the ship mounted and dunking platform methods may, under certain circumstances be overcome by installing the data gathering unit in a submersible vehicle. The requirement for a stabilization unit is completely eliminated since the entire platform is unaffected by the motion of the surface. The manoeuverability of the vessel will allow both visual and acoustical observation of targets from all angles and ranges. The various hazards can be approached without danger to the equipment during adverse weather conditions. The variable depth capability will permit a full study of the thermocline and its effects on sonar range and performance. Methods of overcoming these effects such as varying the transmit tilt angle, can be implemented quite easily as the sub is held in a fixed position. However, the operational complexity and risk factor may be a great disadvantage.

6.4 The Proposed Method

The implementation of the data gathering phase for the hazard detection/collision avoidance sonar system is to consist of a dunking transducer sonar system (omnidirectional) installed in a helicopter provided by Transport Canada. Since these helicopters are already commissioned on the various vessels operating in the Arctic, a rearrangement of their daily missions could be utilized.

This method would provide the best, most efficient means of collecting data in the shortest possible time. It allows for both visual and acoustic observation of ice hazards with minimal risk. Short missions could be conducted daily, weather and schedule permitting, that would cover a wide territory, taking advantage of only the best data gathering conditions. This modular, relatively low weight system would permit easy and fast assembly and installation. The estimated weight of the total system, cables included is 300 kg (600 lb).

7. SCHEDULE OF ACTIVITIES

A block diagram of the schedule from April 1983 to April 1986 is incorporated in Fig. 10.

7.1 Data Gathering Phase

In preparation for the data gathering phase certain objectives have to be met prior to June 1984. (planned Arctic data gathering expedition). A sonar system consisting of the transducer and additional equipment needs to be assembled prior to the actual data gathering phase.

The data storage system will involve the purchase of a suitable computer and data storage/retrieval unit. This unit would be interfaced to the sonar system in the same timeframe.

This will include the design of a special hardware interface and a software program for control of the storage system. At this point, the entire data gathering system should be tested during May of 1984, in readiness for the actual data gathering, which should commence in July and be completed in August 1984.

7.2 Development Phase

This phase should begin as early as possible in conjunction with the preparation for the data gathering to ensure that the most practical means are employed to solve the known requirements of the system. The completion of this phase cannot occur, prior to analyzing the data from the Arctic environment.

This could be completed in January 1985, however, a summary of information from the Data Gathering should be submitted outlining any options available prior to completion of the Development phase, (naturally the choice of options may have a profound effect on the remainder of this schedule).

Additionally, a transducer capable of withstanding pressures to 10,000 psi (3.3 kPa) should be completed by this same date. However, this completion date is not as critical since it will only be required at the start of the system testing.

7.3 Design Phase

The design phase should be underway in January 1985, however, prior to this date some of the known required electronic functions will have entered or completed the breadboard stage of design. The completion of the design stage will greatly depend on results of the Arctic environment data. The estimated completion is April 1985.

7.4 Construction Phase

This phase should commence October 1985 utilizing standard manufactured modules wherever possible, allowing the completion of the prototype in September 1986. On completion of performance testing phase, any required modifications will be incorporated to bring the unit to production level.

7.5 Testing Phase

Simulations should be performed on the final sonar system using the recorded data obtained during the data gathering phase of the project. This will demonstrate the system's ability to detect various ice hazards under the exact acoustic conditions that exist in the Arctic.

Further testing of the system's beamwidth, source level and receiving response will require a test facility with long range capability. This is due to the anticipated narrow beamwidth requirement. A suitable site for this testing is the Defense Research Establishment's (D.R.E.) sonar barge located in the Bedford Basin, Nova Scotia. This should occur between September and October 1985.

The final unit should also incorporate automatic fault location self-diagnostic (A.F.L.). This enables the operator to perform a self-test on the unit and locate any part that is not functioning according to specification.

The transducer design will come under the scrutiny of Canadian Streamship Inspection (C.S.I.). All mechanical testing required by the branch of Transport Canada will be carried out and results made available.

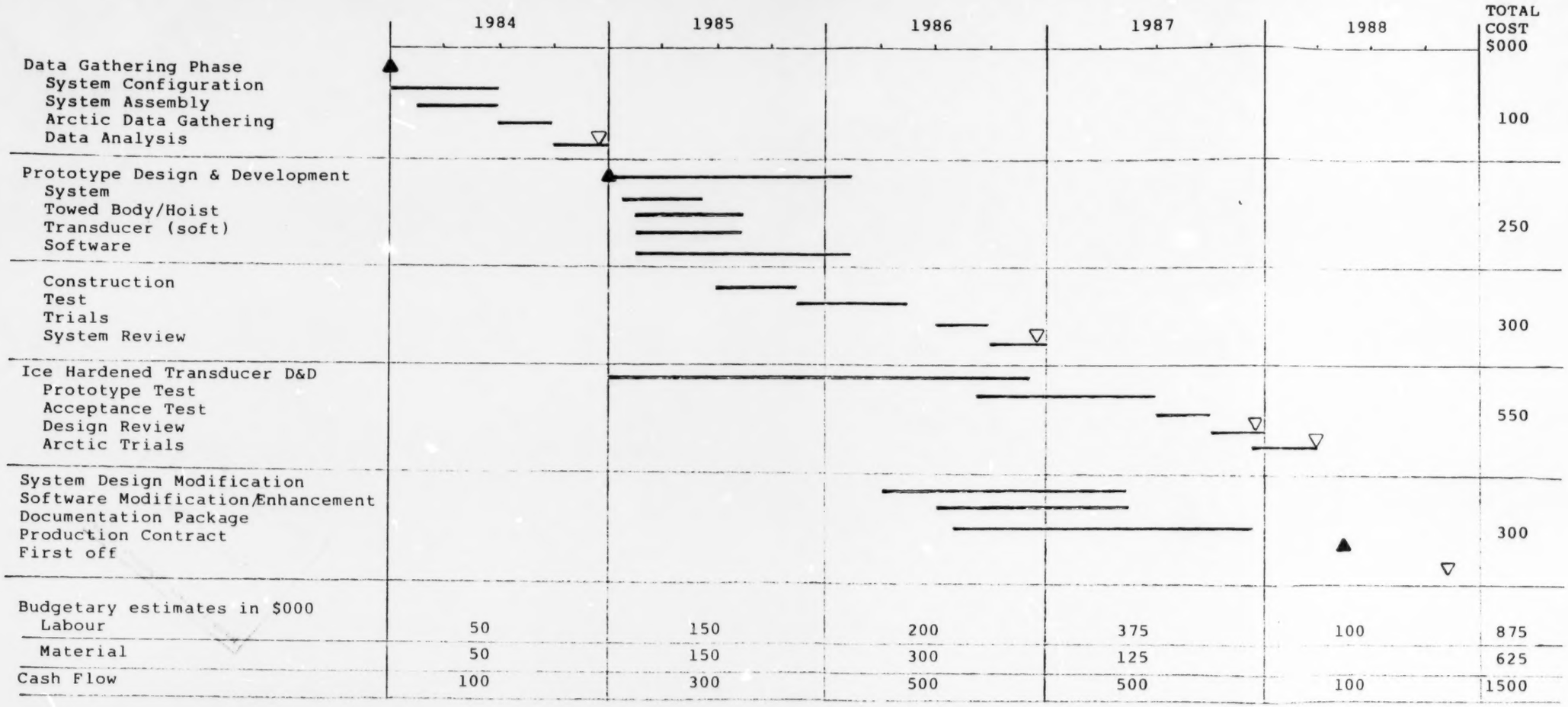
Finally, the sonar will be installed in an Arctic class vessel, operating in the vicinity of hazardous ice forms. This will conclusively demonstrate the capability of the system as a stand-alone unit, or in conjunction with other forms of ice detection equipment.

8. CASH FLOW AND BUDGETS

Cash flow projections have been prepared for Phase 2 to Phase 6. (Phase 1 is Proposal Preparation).

The projections for Phase 2 - Data gathering phase are relatively certain. However, the work required in subsequent phases will be largely determined by the conclusions developed in Phase 2. Therefore, these future cash flows are rough estimates based on present knowledge and assumptions.

Phase 2 - materials cost estimates are relatively accurate since they reflect the intended use of commercial sonar modules currently manufactured.



Budgetary estimates in $000						
Labour	50	150	200	375	100	875
Material	50	150	300	125		625
Cash Flow	100	300	500	500	100	1500

▲ = Start of Phase
▽ = Completion

FIGURE 10 PROJECT SCHEDULE & BUDGETARY ESTIMATES